upon the readjustment of the soft parts of the animal.

Jaworski evolves and develops another theory of phylogenetic relationship which seems so untenable that it may be disregarded —namely that the strongly plicated oysters such as the *Ostrea edulis* are the descendants of the strongly plicate *Gryphæas* of the Mesozoic. The surface sculpture is not a fundamental character among the oysters and there is no reason to search for its cause in distant ancestral relationships. Regarding the phylogenetic significance of *Heterostrea steinmanni* it would seem that it was an entirely too specialized form to have given rise to the subsequent *Ostrea* stock.

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SPECIAL ARTICLES

THE CHEMICAL DYNAMICS OF LIVING PROTOPLASM

Van't Hoff's formulation of the laws of chemical dynamics has proved so stimulating to various fields of chemistry that it may be expected to be similarly useful if it can be applied to the activities of living protoplasm.

The writer finds that by measuring the electrical resistance of living tissues it is possible to follow the progress of reactions in protoplasm in the same way that van't Hoff followed the progress of reactions *in vitro*. It therefore becomes possible to apply van't Hoff's methods and formulæ directly to protoplasm in its living and active condition. The following example will suffice to show how this may be accomplished.

The electrical resistance of living tissue of the marine alga *Laminaria* was measured by a method which has been previously described.[1] The tissue had in sea-water a resistance of 980 ohms.[2] On being placed in NaCl .52*M* (which had the same conductivity as sea-water) the resistance fell after 10 minutes to 855 ohms and after 20 minutes to 745 ohms: it continued to fall rapidly and finally became stationary at 320 ohms. This represents the death point. The total change produced by the NaCl was 980–320 = 660 ohms.[3] In order to find out whether this change had been produced in such a way as to correspond to a known type of chemical reaction the amount of change was measured at brief intervals. The results are given in Table I.

TABLE I

t=time in Minutes	Resistance	x=loss of Resistance	$a-x$	$\frac{a}{a-x}$	$\log_{10}\frac{a}{a-x}$	$k=\frac{1}{t}\times\log_{10}\frac{a}{a-x}$
0	980	0	660			
10	855	125	535	1.234	.0913	.00913
20	745	235	425	1.553	.1911	.00955
30	655	325	335	1.970	.2944	.00981
40	590	390	270	2.444	.3881	.00970
50	540	440	220	3.000	.4771	.00954
60	495	485	175	3.771	.5764	.00961
70	465	515	145	4.551	.6581	.00940
80	440	540	120	5.500	.7403	.00925
90	405	575	85	7.765	.8901	.00989
100	395	585	75	8.800	.9444	.00944
110	380	600	60	11.00	1.0414	.00947
120	366	614	46	14.35	1.1568	.00964
130	359	621	39	16.91	1.2281	.00 45
140	351	629	31	21.29	1.3282	.00949
150	345	635	25	26.40	1.4216	.00948
160	339	641	19	34.74	1.5408	.00963
200	320	660	0	dead		.00953= Average
250	320	660	0			
300	320	660	0			

a = total change = 980–320 = 660 ohms.
Temperature 18.5° C.

According to van't Hoff we can determine from such measurements whether one, two or more substances are taking part in the reaction. If only one substance takes part (or if two substances take part but only one of them changes its concentration noticeably) the reaction is said to be of the first order (monomolecular) and it proceeds according to the formula

$$k = \frac{1}{t} \log \frac{a}{a-x},$$

in which t is the time which has elapsed between the beginning of the reaction and the taking of the measurements, x is the loss in

[1] Science, N. S., 35: 112, 1912.

[2] If left in sea-water this resistance is maintained for a long time.

[3] The fact that this action of NaCl may be antagonized by $CaCl_2$ does not affect the subsequent discussion.

resistance at the time t, a is the total amount of change in resistance when the reaction is completed and k is a constant (called the velocity constant) which indicates the speed of the reaction. If the reaction is of the first order (monomolecular) k should come out constant provided the temperature be kept constant during the reaction.

In this case a, which represents the total amount of change, is $980 - 320 = 660$ ohms, while x represents the loss of resistance after 10, 20, 30 minutes, etc. In the calculations common logarithms have been employed. It will be seen from the table that k is nearly constant: the variations are no greater than are commonly found in measuring chemical reactions in the test tube.[4] It is probable that they would have been smaller if the temperature could have been kept perfectly constant.

The simplest interpretations of this are as follows. We may suppose that the NaCl reacts with some one substance in the protoplasm but that so little of the NaCl is used up that its concentration changes but slightly.[5] It can be shown by analytical methods that the concentration of the NaCl suffers but little change. In all of the experiments more than 1,200 c.c. of NaCl .52M were employed to 10 c.c. of tissue.

It should be added that if a series of reactions is involved what we measure is practically the rate of the slowest of the series.

An alternative interpretation is that the loss of resistance is due to the spontaneous change of some one substance in the protoplasm, a process which goes on with extreme slowness until catalyzed by the NaCl. This view is of great interest because it implies that the process of death is always going on even in a healthy and growing cell.

If we suppose the NaCl to act as a catalyzer it may be that the reaction which it accelerates is the hydrolysis of some substance in the protoplasm. This would behave as a reaction of the first order since the concentration of neither the NaCl nor the water would undergo much alteration. The reaction might be compared to the hydrolysis of cane sugar (when catalyzed by acid) which behaves as a reaction of the first order.

On this view death would be due to the hydrolysis of some substance (probably protein) in the protoplasm. There is a variety of evidence that death is accompanied by such hydrolysis.

We should not overlook the possibility that the opposite process (dehydration) would give quite the same result. Death is often accompanied by the coagulation of certain proteins. According to some authors coagulation involves dehydration while according to others it is a process of hydrolysis.[6]

We may now consider other possible suggestions. One is that the progress of the reaction is determined not by the number of substances taking part but by diffusion. The NaCl[5] diffuses inward (and the other salts outward) rapidly at first, then more and more slowly, thus affording a certain likeness to the curve of a reaction of the first order. The incorrectness of this interpretation is shown by a study of the temperature coefficient. The temperature coefficient of diffusion is low, the increase in the rate of diffusion being less than 30 per cent. for an increase of 10° C. The increase in the velocity of the reaction of NaCl with living protoplasm amounts to over 150 per cent. for an increase of 10° C., which

[4] The most constant value of k is obtained when the material is sound and is taken directly from the ocean just before the beginning of the experiment. The temperature should not be allowed to rise much above that at which the plants have been growing. The fronds should be neither too old nor too young, and should not have reproductive organs. Fronds should be selected which have the mechanical properties requisite to cause the disks to lie flat in the apparatus when it is closed, but to separate spontaneously when it is opened. Failure to realize these conditions, as well as other imperfections in technique, may produce irregular fluctuations in the value of k.

[5] This applies as well if we suppose that the NaCl in uniting displaces some other substance (*e. g.*, $CaCl_2$) provided the latter is not allowed to accumulate too much in the solution.

[6] The addition or splitting off of H ions would also behave as a reaction of the first order.

shows clearly that we are dealing with a chemical reaction. We must, therefore, exclude the interpretation that diffusion is the determining factor.[7]

Another suggestion is that the result is due merely to the fact that the majority of the cells are more accessible to the reagent or less resistant to it than the rest, so that more cells are killed in the first minute than in the second and so on. But if this were the case we could not, after a lapse of ten minutes (when the loss of resistance already amounts to 125 ohms), restore the tissue to its initial resistance by replacing it in sea-water. This can be done and there is no evidence that the tissue is in any way injured by such treatment with NaCl.[8] The same piece of tissue may be treated with NaCl (for five minutes) and replaced in sea-water several times each day for ten days in succession without showing any sign of injury.[9]

This leads us to the following conclusion. Since the effect of NaCl is within wide limits completely reversible, without production of injury, *the conception of the chemical dynamics of living protoplasm here developed applies not only to reactions which produce death but also to reactions which involve no injury and which form a normal part of the activity of the cell.* This conclusion is fully confirmed by experiments with a variety of other substances.

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[7] There are other important reasons opposed to the suggestion that diffusion is the determining factor. One of these is the length of time required for the process. If tissue is transferred from sea-water to sea-water diluted with one or two volumes of distilled water, there is a change of resistance which continues until equilibrium has been restored by diffusion. This process at 18° C. does not take more than ten minutes, whereas nearly three hours would be required for the reaction with NaCl which we have been measuring.

[8] This and other experiments show that the increase in the conductivity of the protoplasm is not to be attributed to an increase in the concentration of electrolytes within the cell but rather to a decrease in the viscosity of the protoplasm (or to an increase in some other factor which facilitates the passage of ions).

[9] Science, N. S., 36: 350, 1912.

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

SECTION H—ANTHROPOLOGY AND PSYCHOLOGY

At the recent annual meeting of the American Association for the Advancement of Science held at Atlanta, Georgia, December 29 to January 2, Section H—Anthropology and Psychology—participated in four sessions. Tuesday afternoon was devoted to a "general interest" session at which Professors Max Meyer and Lightner Witmer spoke. Wednesday morning was given over to a joint meeting with the Southern Society for Philosophy and Psychology; Thursday morning to a joint session with Section L—Education, and Thursday afternoon to a joint session of all three of these organizations. In all some twenty-two papers were presented.

The following officers were elected: *Vice-president of the Association and Chairman of the Section,* Dr. Clark Wissler, of the American Museum of Natural History; *Member of the Sectional Committee* (to succeed Dr. G. A. Dorsey), Professor Lightner Witmer, of the University of Pennsylvania; *Member of the Council,* Professor Max Meyer, of the University of Missouri; *Member of the General Committee,* Professor L. R. Geissler, of the University of Georgia.

The following twelve papers were presented under the auspices of Section H:

The Present Problems of Physiological Psychology: Max Meyer.

Psychologists generally are beginning to realize that the study of consciousness is only a secondary, an auxiliary branch of psychology. But it is a mistake to think that psychology can be defined simply as the study of behavior. The study of plant behavior is the business of the botanist. Nothing forbids, of course, interest in plant behavior on the part of the psychologist save common sense, which would call a man a botanist if he is more interested in plant behavior than in human life. In a similar way the study of animal behavior must be regarded as primarily the task of the zoologist. And the study of human behavior seems to be largely the province of the sociologist (including under "sociology" as a special branch the science of education). Is then